Project Report: Habitable Planets

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Project Progress

Co−Is Hollenbach and Laughlin, working with outside collaborators F. Adams and U. Gorti, have been modeling the photoevaporation of protoplanetary disks around young stars. During the past year, they have finished a calculation of the evaporation of disks around low mass (solar−type) stars caused by the external ultraviolet radiation from a nearby massive star in the birth cluster (Adams et al. 2004). It is shown that photoevaporation can often affect the region where, at least in our solar system, the giant planets form. The rapid photoevaporation of gas in as close as 10 to 20 AU also then means that gas disappears quite rapidly in the inner regions as well. Hollenbach and Adams (2004 a, b) applied the results of the Adams et al. paper to study whether photoevaporation could explain a sharp cutoff in the Kuiper Belt, the sharp drop of hydrogen content in the giant planets Neptune and Uranus compared to Saturn and Jupiter, and the deficit of planets seen in large clusters. For conditions similar to the large cluster observed in the Trapezium of Orion, the conditions are so harsh—especially in the inner parts of the cluster—that all giant planet formation may be quenched, and even terrestrial planets may be strongly affected.

Co−I Greg Laughlin and collaborators at University of California , Santa Cruz have been investigating the dynamical viability of possible terrestrial planets orbiting in the habitable zones of known planet−bearing stars. Of particular interest are potentially habitable orbits in systems with several known planets (e.g. GJ 876, or 55 Cancri). Because of the large amount of computing required, and because of intense public interest in both extrasolar planets and habitable worlds, they are building a distributed computing solution for this problem along the lines of the seti@home model. Specifically, we are designing a public user interface that leverages the existing www.transitsearch.org candidates site (see http://www.ucolick.org/~laugh/) and which uses the Berkeley Open Infrastructure for Network Computing Package (http://boinc.berkeley.edu/) to handle the back−end aspects of the distributed application.

Collaborators Segura and McKay, and Co−I Toon, investigated analytical solutions to the equations governing a runaway greenhouse to show that there is a region in flux and temperature space where there are actually two stable solutions. Both are stable and correct. The warm solution can only be reached if there is a significant temperature perturbation to the system, such as a large impact. They are investigating different regions of phase space and assess how large an impact would be required to produce a runaway greenhouse for a given planet such as Mars.

Co−I Hollingsworth has conducted both mechanistic modeling and fully coupled climate modeling studies using a variety of modeling tools to model the climate of the Earth and Earth−like planets under extreme but plausible environmental conditions. Adapting a mechanistic climate modeling approach helps identify important positive and negative feedbacks between various components of the climate system. During this investigation, the focus has been on two main areas of research: (a) mechanistic fully−coupled climate simulations using the KNMI/ECBILT modeling system; and (b) realistic and extreme coupled climate simulations using the NCAR/CCM.

Co−I Davis and Collaborator Richard continue to investigate possible sources of turbulence in the protoplanetary nebula that will enhance mixing and inter radial transfer. They published a short contribution (Richard and Davis) on this subject in Astronomy and Astrophysics. They used this and related information to compute the migration of a condensation front (thought to be a factor in the rapid growth of gas giants such as Jupiter). A paper is submitted on this subject and a presentation was made at a recent conference on chemistry in the protoplanetary nebula.

Collaborators Rabbette, Pilewskie, and McKay, together with Co−I Young, submitted a paper for publication showing that the clear sky upward longwave flux as a function of sea surface temperature (SST) near SST = 300K, observed over the tropical Pacific Ocean, exhibits the classic signature of the runaway greenhouse. The key role water vapor plays in the tropical clear sky greenhouse effect was investigated. The study highlights the fact that the water vapor greenhouse effect depends not only on the total column integrated amount, but more importantly on the vertical distribution of the tropospheric water vapor.

Highlights

- It is shown that photoevaporation of a protoplanetary disk can often affect the region where, at least in our solar system, the giant planets form. The rapid photoevaporation of gas in as close as 10 to 20 AU also then means that gas disappears quite rapidly in the inner regions as well. Therefore disk photoevaporization may be a limiting factor for the formation and evolution of habitable planets.
- Large impacts appear capable of throwing an otherwise stable planetary atmosphere into a runaway greenhouse state. There is evidence this may have happened on Mars.
- The vertical distribution of water vapor in a planetary atmosphere should be an important factor in the evolution of a runaway greenhouse

state. The importance of the vertical water vapor distribution has been shown for the local super–greenhouse occurring over the terrestrial tropical Pacific Ocean.

Roadmap Objectives

- ***Objective No. 1.1:*** Models of formation and evolution of habitable planets
- ***Objective No. 2.1:*** Mars exploration
- ***Objective No. 4.3:*** Effects of extraterrestrial events upon the biosphere

Mission Involvement

Mission Class*	***Mission Name (for class 1 or 2) OR Concept (for class 3)***	***Type of Involvement*****
1	Kepler	Co–Investigator
1	Mars Odyssey	Background Research
2	Mars Lander 200	Background Research
2	Terrestrial Planet Finder	Background Research
1	Spitzer Space Telescope	Co–Investigator,Background Research

* Mission Class: Select 1 of 3 Mission Class types below to classify your project:
1. Now flying OR Funded & in development (e.g., Mars Odyssey, MER 2003, Kepler)
2. Named mission under study / in development, but not yet funded (e.g., TPF, Mars Lander 2009)
3. Long–lead future mission / societal issues (e.g., far–future Mars or Europa, biomarkers, life definition)

** Type of Involvement = Role / Relationship with Mission
Specify one (or more) of the following: PI, Co–I, Science Team member, planning support, data analysis, background research, instrument/payload development, research or analysis techniques, other (specify).